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A Systematic Climatology Report of Aviation Weather Hazards on Yangon Airport Region

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Abstract: The primary goal of the research was to examine the aviation climatology analysis of the thunderstorms and fog on study area based on the statistical evaluation of the meteorological station's observation data. Weather is a critical factor in aviation, profoundly affecting aircraft operations and safety. The global aviation industry, with a staggering economic impact of $3.5 trillion and contributing 4.1 percent of global GDP, relies heavily on weather data and analysis. Study used METAR data from Myanmar's Yangon International Airport (VYY). Analysis of METAR, flight delay and accident data revealed that the influence of thunderstorms and fog might have had a direct or indirect impact on most accidents over study area. The frequency analysis method were primarily used in this study and the new method of fog event analysis came out. The two meteorological occurrences, thunderstorm rain (TSRA) and fog (FG), are also high frequency at VYY in a year and TSRA is a larger risk than FG for aviation operation due to its relative other weather phenomena. The July is the maximum TSRA occurrence month and total annual frequency analysis revealed that TSRA days are becoming more common year by year because of study. In addition, the total number of days with fog varies from 23 to 91 per year, with the most frequent time of day being between 2300 and 01:00 UTC. The conditions where the fog was most likely to form were those when the minimum temperature fell between 16 and 27 °C (liquid fog). The study raises a new question and a new possibility for viewing climatology from a new perspective. The insights gained from this report can contribute to the development of tailored weather forecasting and alert systems for pilots and airport personnel. Further deep study for systematic prediction of each hazards are leaved for future work.

Keywords: *Aviation Weather, Fog, METAR, Myanmar, TSRA, VYYY*

Conflicts of interest: None
Supporting agencies: None

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1. Introduction

The economy of wealthy nations like China, landlocked nations like Laos, and small island countries like Madagascar all lean highly on the aviation industry. Similarly, the essential factors of long-term economic growth is the aviation industry also. Additionally, it serves as a major catalyst for various forms of economic activity such as domestic trade, military operations, and tourism. The Air Transport Action Group estimates that in 2022, the aviation sector will have supported 87.7 million jobs globally and created 961.3 billion dollars in direct gross benefits (Figure 1). In 2022, aviation will contribute 4.1 percent of the world's GDP and have a $3.5 trillion global economic impact (Industry High-level Group, 2019). Despite being in the monsoon region of Asia, the geography and topography of Myanmar have a significant impact on its climate. Myanmar has three distinct seasons: hot and dry summer (March to May), hot and wet southwest monsoon (June to September), and cold and dry northeast monsoon (October to February) (britannica.com, 2021). The only monsoon circulation or winds that are significant to its seasons are those in the Northeast and Southwest. Monsoon season, the season of crowd convective activities may lead to high risk of weather related aircraft accident and delay in airport operation (Kulsea, 2002). The risks of flying through a thunderstorm include high turbulence, wind shear, downbursts, icing, lightning, and hail. Pilots are therefore encouraged to divert from their flight plans in order to avoid significant convective activity (González-Arribas et al., 2019). As a result, aircraft should avoid them. When these variations are added up over several flights, they result in considerable interruptions to air traffic. Air Traffic Control Management authorities must then handle such disturbances, frequently by holding, postponing, or cancelling other aircraft. Myanmar was dramatically expand its airport capacity, especially for traffic in and out of Yangon, the business capital are also increase during the last decade after chaginh country economic policy (Group, 2014). The study airport, Yangon International Airport (VYYY), which serves around six million passengers annually and has flights to more than 50 destinations in 14 different countries, is the crowded airport in Myanmar (PricewaterhouseCoopers, 2012). It is located at an altitude of 33.6 meters (110 feet) above sea level and has one runway. VYYY is a home place for all Myanmar airlines as well as around 30 international airlines are used in daily for their business (DCA, 2019).

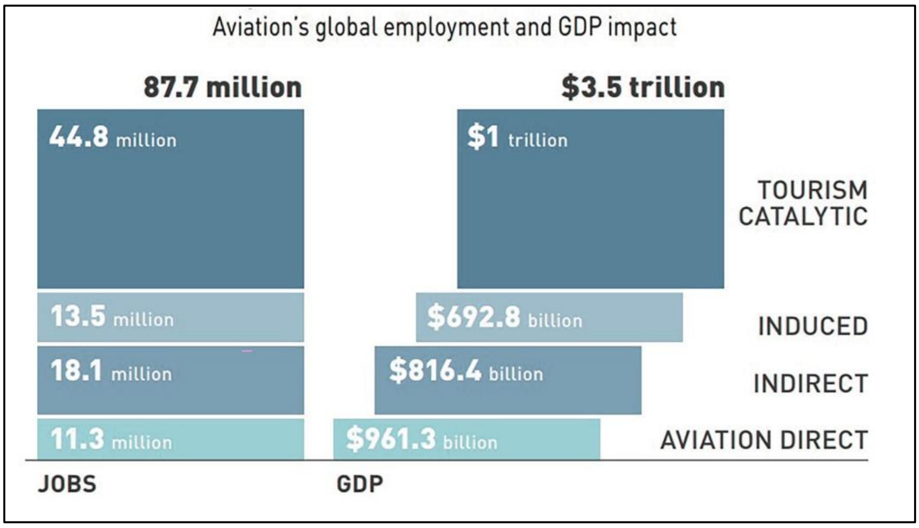

Figure 1: Global GDP Impact and Aviation employment Statistic(2022) (Gittens et al., 2019)

The airport are often closing it services under severe weather condition and other technical issue, especially heavy rainfall by thunderstorms. Airport operators are only person who have the authorities to close an airport, and this action would only be implemented in the serious situations. Air weather services (AWS) don't have the jurisdiction or capability to close an airport, even in cases of serious weather on an airfield (Dorian & Robinson, 2018). Thus, the aircraft's departure and arrival operations are determined by the weather situation, ground equipment's, the qualification of AWS members and the flight crew (Baars et al., 2001). Low cloud cover (cloud base below 1000 ft. above ground level), fog, and heavy precipitation can reduce visibility at or near airports, and fog, runway icing, lightning and thunderstorms can cause significant delays to flight schedules. Fog can induce low horizontal visibility (less than 1000 m), which can limit ground and air movements, hence a low visibility operation can also affect capacity at an airport (WMO 2007). Since many modern airplanes can now land and take off in extremely low visibility, aircraft ground movement safety might occasionally be the biggest capacity constraint (BRARY, 2021). However, during a Thunderstorm Rain (TSRA), airplanes cannot have the ability to land but also take-off in some phases land and must instead be diverted or rerouted around the storm cells. Usually, ground operations may typically need to be suspended until a storm passes near an airport due to nearby thunderstorms. The temporal and spatial data distribution, and variations of fog and thunderstorm occurrence are therefore essential for understanding fundamental climate science as well as for societal applications like aircraft and airport operations. According to the National Transportation Safety Board's (NTSB) analysis of weather-related circumstances that influence near- surface aircraft operations, wind and turbulence caused 1381 accidents, visibility, ceiling height (hc), and precipitation-related accidents occurred 485 times, and aircraft icing caused 150 accidents between 2003 and 2007 (Fultz & Ashley, 2016). The primary goal of the research is to examine the benefit of aviation climatology analysis over VYYY (***Figure 2***). Based on the statistical evaluation of the meteorological station's observation data, the studies has examined the individual impact of the thunderstorms and fog on study area, which are most significant impact on airport operations. By using a significant statistical method, we investigate the climatology of the thunderstorms and fog that have the greatest impact on aviation and/or airport operations. The study is intended not only for aerodrome and aircraft operations but also for a far range of all aviation industry's users. This summary can be used by experts from various fields for scientific research in addition to the prospective consumers stated above.

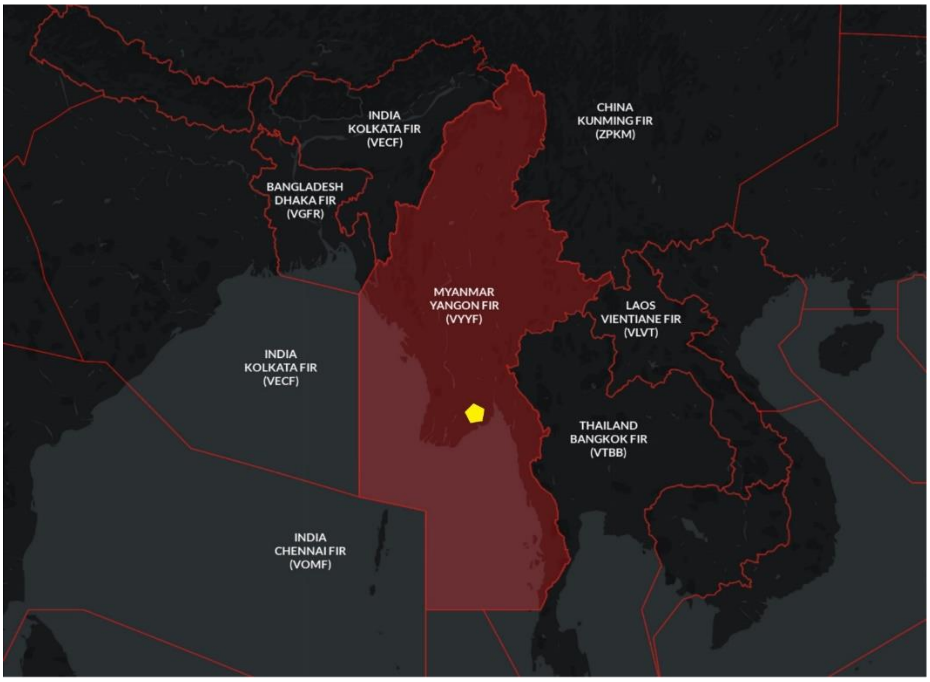

Figure 2: The red box indicates the VYYY controller coverage region for the Flight Information Region (FIR) and the study airport area (Yellow Polygon) (OPSGROUP, 2021)

2. Materials and methods

The world stage institutions like the World Meteorological Organization (WMO) issued developed guidelines for the analyzing of climatologic data, that are adhered to when producing statistical data together with the International Civil Aviation Organization (ICAO, 2018). Count the 187038 times of thirty-minute observation data (aerodrome METARs data) from VYYY from 2003 to 2021. The shown observation station data of the VYYY satisfies all predetermined criteria for representative, continuous, and trustworthy data because it holds holds a Quality Management ISO 9001: 2015 Certificate, which was issued by the SGS international organization. Also its passing through yearly audit by ICAO (Standards & Division, 2016). The Aviation Safety Network (ASN) and the ICAO Safety API Data Service (ICAO, 2019) are the sources of information on accidents and flight delays. YIA Service Company Limited provides support for the aerodrome's data. The climatological analysis is done for each day, month and season to figure out the average frequency of meteorological events in the studied area. The frequency of the category is divided by the total number of participants, and then multiplied by 100% to get the percentage. A score's frequency in a set of data refers to how frequently that score appears. (Carlson & Winquist, 2014).

$$\text{Frequency Percentage} = \frac{\text{Frequencies of element}}{\text{Total of Observation Times}} * 100$$

Additionally, findings for TSRA and FOG were produced using CDO, IBM SPSS, and MS Excel programs. To determine the statistical significance of the analysis results in this study, 95% confidence student t-test was performed. This method's application to South Asian nations has been discussed in a number of earlier studies (Goodman & Griswold, 2019; Gultepe et al., 2019; Nechaj et al., 2019). In this work, we performed the Pearson correlation analysis to demonstrate the relationship between the variables with a 95% confidence level.

Fog Types Classification

Visibility may reduce below 1000 meters horizontally, resulting in brief periods where fog is present. In this view, a foggy weather is described as a collection of distinct fog episodes that are spaced apart by less than two hours. There is physically or dynamically criteria for the formation of fog prior at least two hours. The following algorithm show each criteria and the concept proposed by following studies.

Table 1: Major mechanism that built the fog formation

Fog Types	Pre stage condition	Major Mechanisms	References
Precipitation (PREC)	Precipitation at onset or hour prior.	Evaporation of precipitation from surface.	Baars et al., 2001 Tardif & Rasmussen, 2007
Advection (ADV)	Wind speed above 1.5 m/s, low clouds below 200 m, in hour prior to onset or clear sky.	Temperature or moisture advection and condensation over a cold surface.	Tardif & Rasmussen, 2007
Cloud-base lowering (CBL)	Low clouds in hour prior to onset with gradual decreasing of base height.	Due to turbulent sub-layer mixing, radiation-induced stratus cloud top cooling causes cooled subsidence and water vapor condensation.	Tardif & Rasmussen, 2007 Dupont et al., 2012 Gultepe et al., 2007
Radiation (RAD)	Clear skies or low clouds in the hour before onset, cooling in the hour leading up to onset, or onset during the colder period, during the hour before sunset and before sunrise. Wind speed less than 1.5 m/s.	Surface radiative cooling due to upward heat flux and turbulent mixing.	Haeffelin et al., 2013 Duynkerke, 1991 Tardif & Rasmussen, 2007
Evaporation (EVP)	Clear skies or an hour after sunrise, followed by a rise in temperature but not dew point.	Increasing rate in surface evaporation by the morning is warming after sunrise followed by turbulent mixing and condensation with cold air.	Arya (2001) Tardif and Rasmussen (2007

Generally, wind is a dynamic driver, whereas temperature and moisture are thermodynamic factors that lead to the fog formation. The half-hourly observational sampling limits any in-depth examination of the behaviour of the characteristics into the mechanisms driving the fog formation and, a proper categorization. However, the study shown the major five kinds of fog in Table 1, including cloud-based lowering fog (CBL), precipitation fog (PREC), advection fog (ADV), evaporation fog (EVAP), and radiation fog (RAD). The primary mechanism causing fog formation is brought on by characteristics of preconditioning obtained five hours before fog formation onset as expressed in *Table 1* (Duynkerke 1991; Arya 2001; Baars et al. 2001; Tardif and Rasmussen 2007; Gultepe et al. 2007; Dupont et al. 2012; Haeffelin et al. 2013).

In the current analysis, the precondition variations in wind, temperature, humidity, and cloud condition from the previous period were evaluated, and each incident of fog was classified into one kind of the fog classifications. If the physical explanation does not correspond to a particular type of fog, the fog is classified as being of an unknown type (UNK**). *Figure 3*** displays the classification strategy.

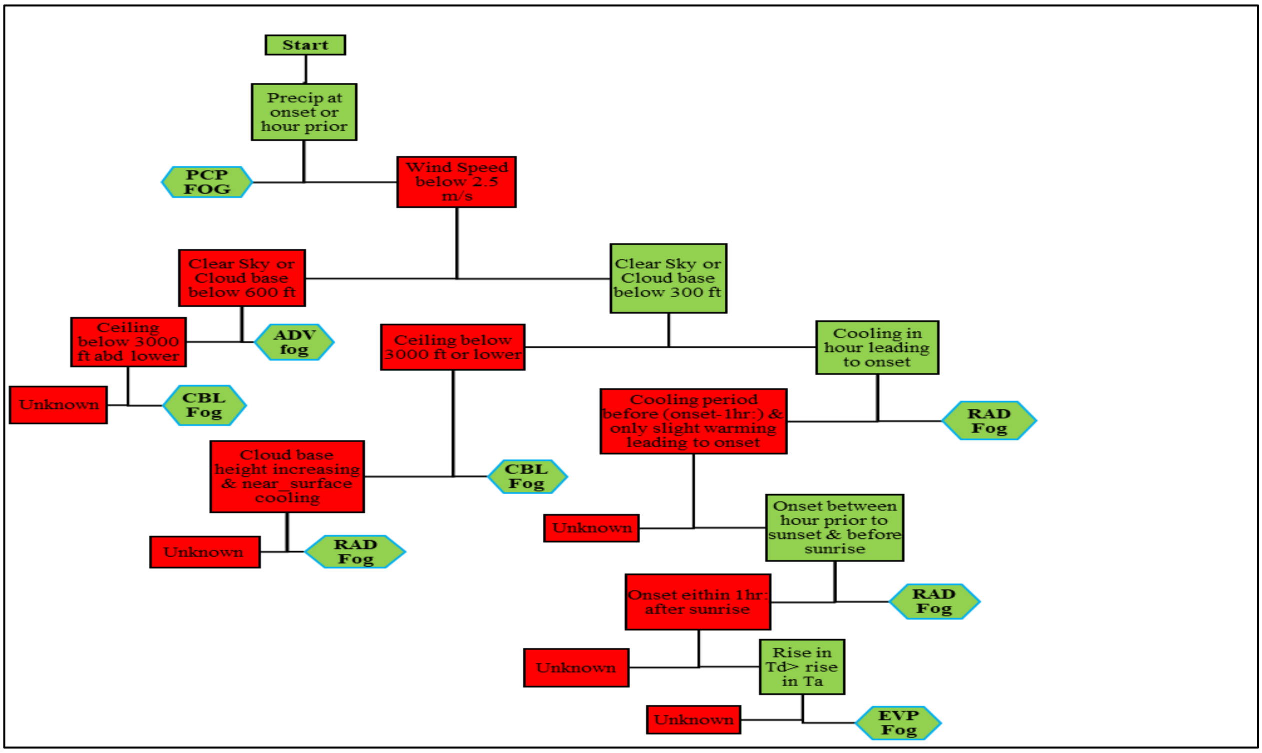

Figure 3: Criteria flowchart for the fog type classification.

3. Results and discussion

Among the most significant elements influencing an aircraft's performance and ability to operate safely is the weather. The benefits of the aviation business also depend on the weather, but as everyone is aware, this is an uncontrolled aspect. Weather causes 7% of all aircraft operation delays, according to an annual survey of the factors that cause the flight delays and arriving late scenario may also related with bad route-weather situations (Figure 4).

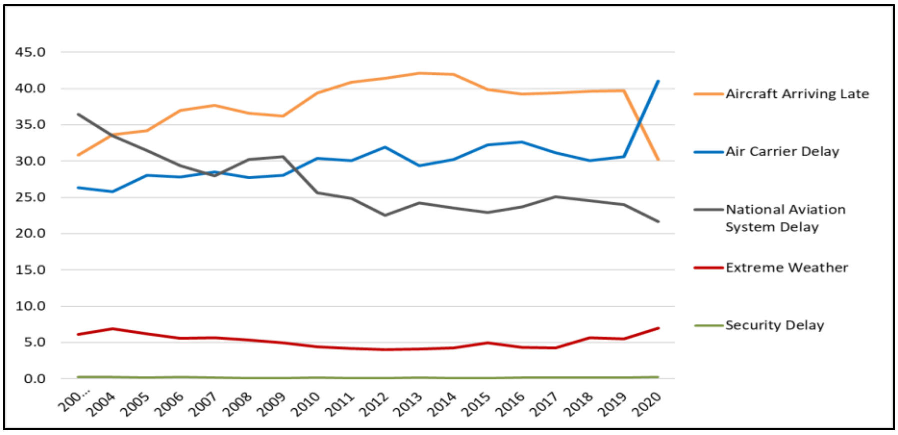

Figure 4: Percentage of total delay minutes attributable to each year's delays

There has a long history between aviation and meteorology. Dominant local weather shifting and severe weather trends can be forecast or predicted by climatology (WMO. 2007). Therefore, the effect of weather on operation of aviation industry is expected to worsen with time until other approaches are discovered. It is not always possible to avoid delays and accident when flying. As of ***Figure 4***, the weather phenomena is the only unpredictability among the five types of aviation delays. It's condemnatory to be prevent from accident and prepared for departure or arrival delays must be anticipated in order for airport operations to smooth. (Lo, 2013).

Aircraft accident analysis

Accidents that can only be attributed to one cause are extremely uncommon. A series of events almost always leads to an accident, and the majority of accident reports make a distinction between the primary cause and several contributing factors. The breakdown of the principal contributing causes in an aviation accident is shown in ***Figure 5***. Accidents caused by the weather are the primary root cause and certain accidents involving loss of control also may be related factors that may result in accidents. Numerous weather-related aeroplane accidents have been reported over VYYY (ICAO, 2019). According to accident records, the influence of thunderstorms and fog may have had a direct or indirect impact on these accidents.

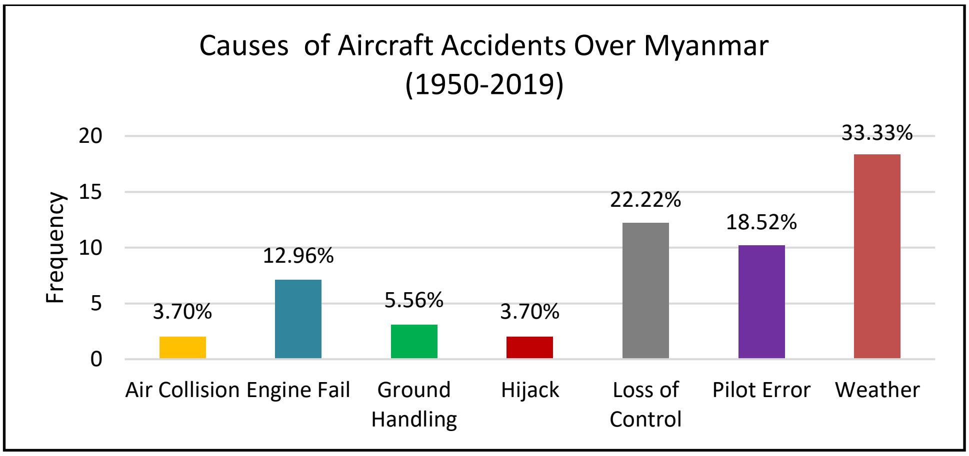

Figure 5: Aircraft accidents analysis over Myanmar (1950-2019)

Thunderstorm Events Analysis

There are 32966 different weather phenomena was occurred, with 1237 days of thunderstorms event during study period. Different colours are used for each meteorological phenomenon to indicate the frequency of each in each , including thunderstorms and fog (Figure 6**)**. The maximum frequencies percentage in February are fog (FG) 11.55%, haze (HZ) 8.35%and mist (BR) 0.86%,. Maximum percentage of Thunderstorm Rain (TSRA) occurred in July (about 12.13%) during study period with Rain (RA) 6.49% and Drizzle (DZ) 9.74%, (Figure 6). After considering a variety of VYYY characteristics, we determined which ones had a material effect on operations. During the crucial interview phase, the operators provided us with a wealth of useful information. The study of accident cases section also displayed how the TSRA and visibility of the weather, in particular, can affect aircraft crashes. As a result, author determined that the TSRA and FG were two meteorological phenomena that have highly concern in aircraft mishaps or operational delays. However, the TSRA presents a higher impact than the fog due to it is connected to some others weather phenomena like wind shear, hail, and lightning.

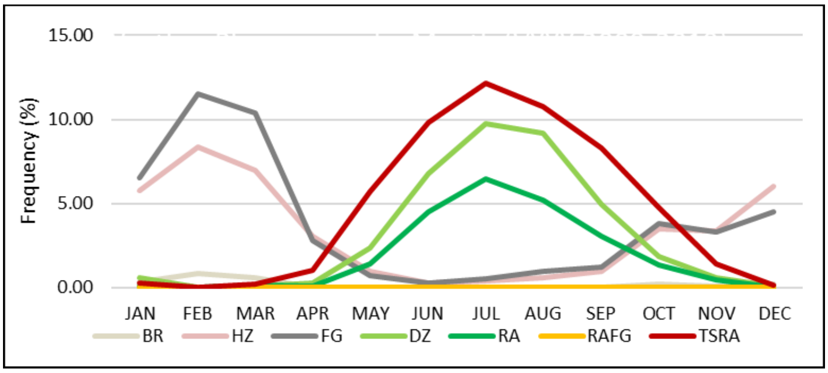

Figure 6: Monthly Frequencies percentage of weather phenomena (2003-2021)

According to Aung et al., (2017) there are three major seasons in Myanmar: summer (March to mid-May), southwest monsoon wet season (Mid-May to October), and northeast monsoon cold season (November to February). Fog and haze meteorological phenomena are more prevalent in the cold season. Thunderstorms have been observed not only during the wet seasons but also during the late dry summer season due to tropical cyclone each year. ***Figure -6*** shows that high number of TSRA event have been found at VYYY for 6 to 8 months.

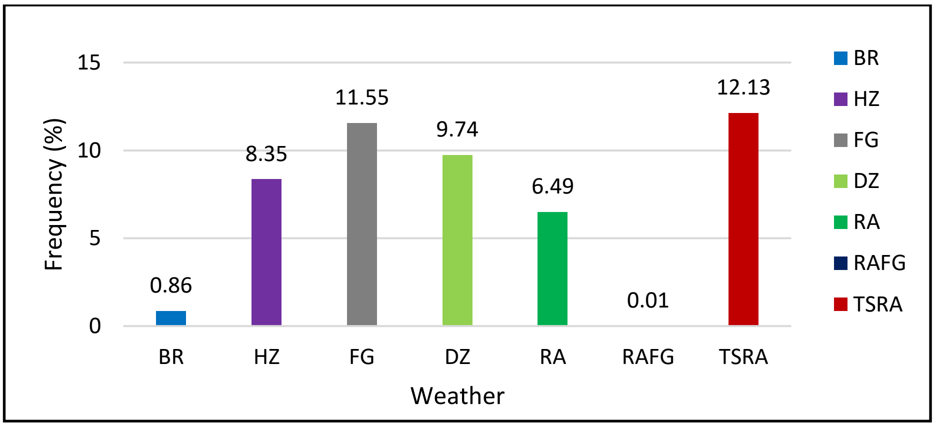

Figure 7: Maximum weather occurrence frequency (%) by phenomenon (2003–2021)

At VYYY, TSRA and FG pose the greatest hazard as ***Figure 7***. Thunderstorms had a stronger impact on both airport and aircraft operations because of the different weather types such as strong winds, hail, lightning, heavy rainfall, and extreme turbulence. The operations of airplanes and airfields are significantly impacted by each of these elements. As a result, the TSRA conditions are thoroughly evaluated in the following sections.

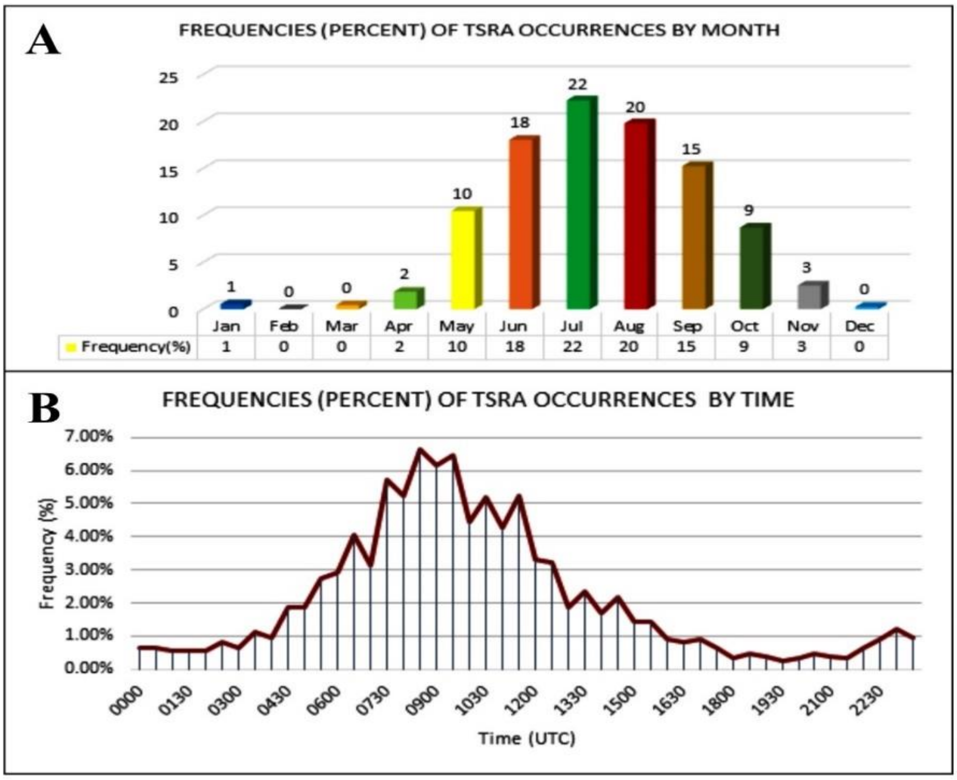

Figure 8: Frequencies (%) Analysis of TSRA occurrences (A) by monthly (B) by daily at VYYY during 2003-2021

Figure 8. A displays monthly and daily frequency of TSRA events during 2003-2021. There are no events in February, March, or December with a 0% frequency, while the maximum frequency in July (22%). The minimum events was occurred in January (1%). The TSRA events are occurred most in wet southwest monsoon season, and maximum in July, is indicated by the seasonal distribution (Figure 8. A). But, the main contributor to thunderstorms is tropical cyclones from the Bay of Bengal or the Western Pacific during other seasons (Zin et al., 2017). The high frequency of TSRA occurred between the hours of 8:00 and 10:00 UTC each day between the years 2003 and 2021(Figure 8. B). While, the minimum frequency occurred between 19:00 and 20:00 UTC. Time zones dictate that local time will be 15:30 in the afternoon at 08:30 UTC. Therefore, on these TSRA days at VYYY, the peak occurrences may have happened between 15 and 16 in the afternoon. For aviation daytime operations, during 00:00 UTC and 04:00 UTC is the ideal window on such TSRA days. The yearly frequencies during a decade period (2009–2019) showed that thunderstorm days are more frequent each year, may be due to the climate change impact. The significant trend projection indicated that thunderstorm occurrence would increase in the future, with the regression strong value (R2 > 0.7) at a level of 95% significant. The fewest number of incidents—255—in the previous years occurred in 2010. In 2018, there were 527 events on average, up from 920 in 2017 (Figure 9).

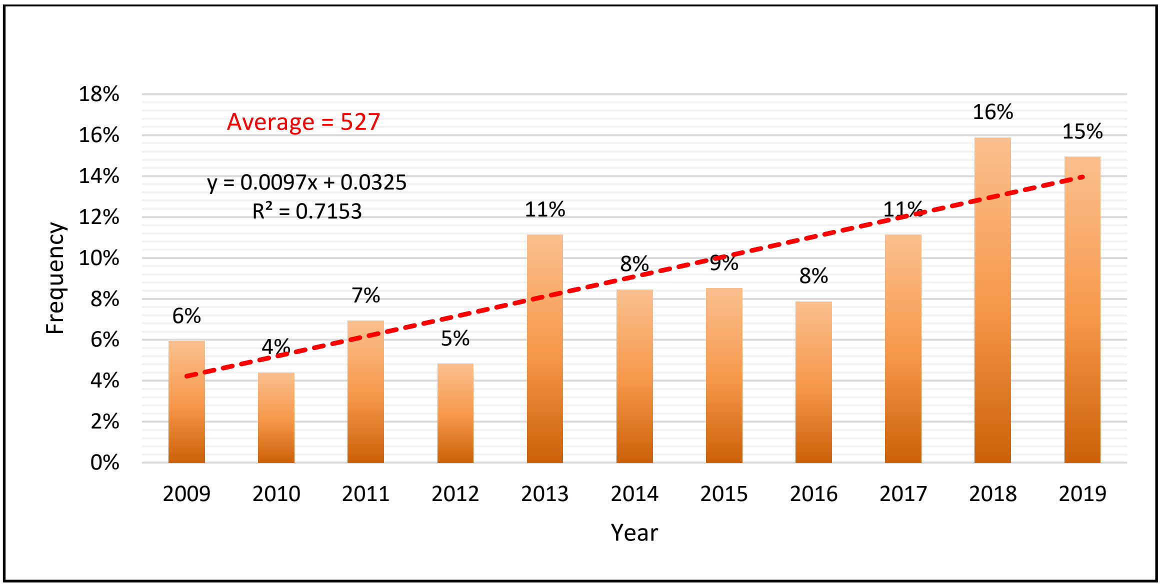

Figure 9: Annual TSRA Occurrence Frequency in VYYY (shaded bar) and Trend (red dotted line) during 2009-2019

Fog events Analysis

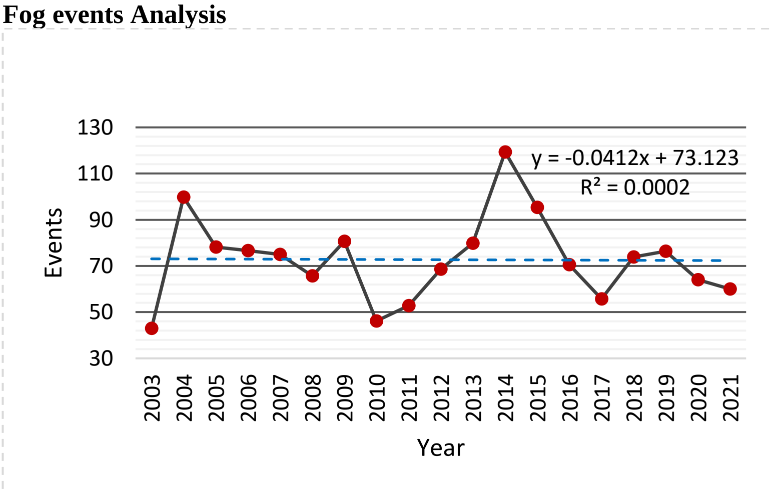

Figure 10: Fog days at VYYY totalled per year, with a linear regression trend (blue dash line) during 2003-2021.

The total fog events are ranges from 43 to 119, as a day (23 to 91 days) during study period. As in ***Figure 10***, the year of the most fog events is 2014, had 119 events, and the year of the fewest is 2010, had 23 events. Due to a paucity of observational data, we have chosen to omit the value for 2003 in this instance.

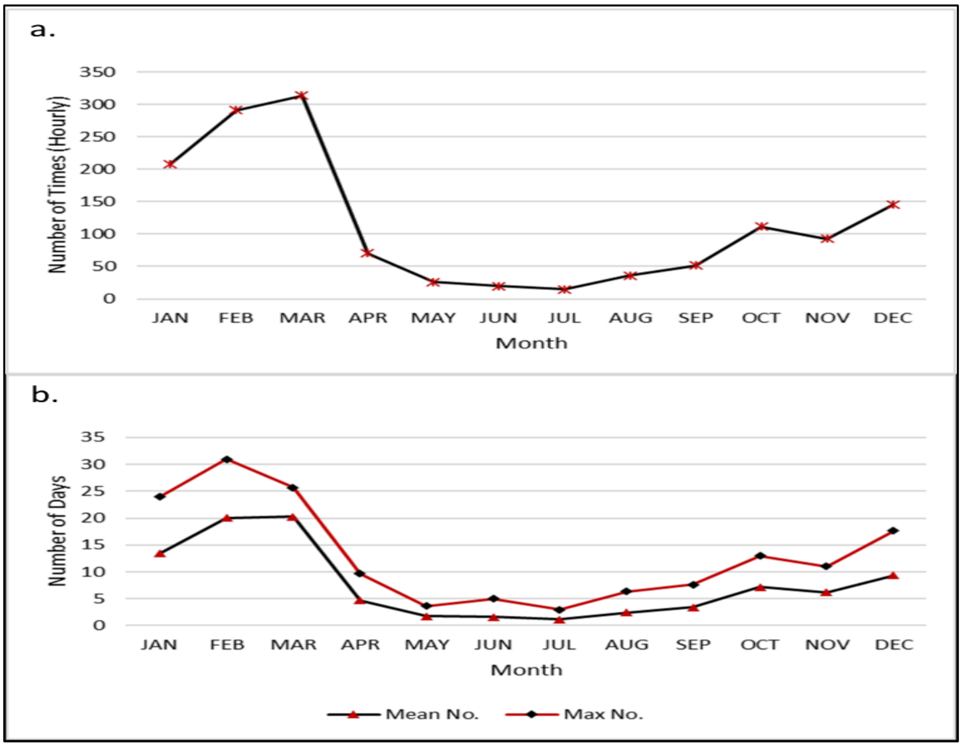

Figure 11: The frequency number (days per month) of (a): total fog events; (b): the absolute maximum (red solid line) and mean (black solid line); at VYYY during 2003-2021.

Considering the seasonal variation in the fog events, most of these occurrences take place in the winter season (DJF) and the first few weeks of spring (MAM) (***Figure 11***). Winter has 1.5 times more fog days than fall and has almost six times more fog days than summer. There were 644 fog event days in the winter particularly (DJF), compared to 71 days in the summer (JJA) and 256 days in the fall (SON).

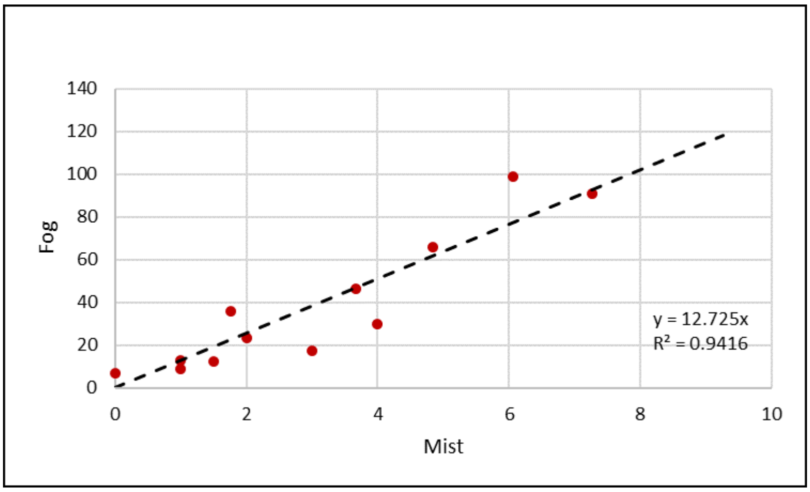

Figure 12: The correlation graph of the total fog events and mist events, during 2003 to 2021. By using linear regression, the dotted line was created. The correlation coefficient (R) is used.

A very high correlation (R=0.92) was discovered when looking at the association between monthly occurrences of fog and mist (1,000 m visibility/2,000 m) during the years 2003 to 2021 (Figure 12). Mist and fog are strongly, favourably, and linearly associated. Accordance to (Quan et al., 2011), weather factors, such as static, stable weather and a lot of vapours, might affect the incidence of mist/haze and fog (for fog). The quantity of aerosols present may also has an impact on the frequency of fog days.

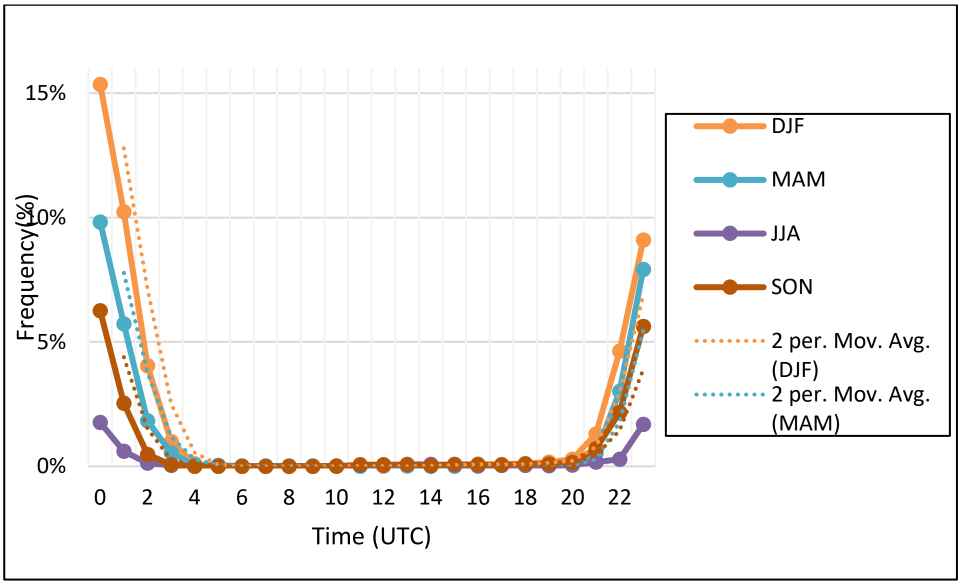

Figure 13: Dashed line represents the moving average, with solid line representing the daily frequency percentage of fog events for VYYY during 2003-2021.

Fog was more common in the morning hours and more frequent than in the summer, as would be forecast for long winter nights. (Figure 13). During the 19-year period, we discovered a statistical association between following fog incidence frequency. Fog events typically start in the later hours of the evening or early the next morning. Throughout the winter, fog occurred within 22:00 UTC to 02:00 UTC and in detail most usually onset between 23:00 UTC to 01:00 UTC during this 18 years study period. In number of time, fog weather events in the winter season and early spring is about four times higher than that in the wet summer and spring. The fog occurrences mentioned in this article are divided into two categories using the two principal mechanisms that cause fog. We looked at data over 19 years (2003-2021), applying the classification criteria established by (Tardif & Rasmussen, 2007) for these two fog kinds. Advection and radiation fog were separated from one another. (e.g., radiation fog, the observed surface wind speed is below 2.5 m s^{-1} (calm or weak wind conditions), the advection fog is associated with moderate winds-greater than 2.5 m s^{-1}). Data from six hours before the fog starts onset are categorized according to certain rules. The aforementioned fog kinds were chosen after 7610 RAD fog events among total all 8289 fog event that occurred during the study period were examined. Events that didn't meet any of the requirements weren't classified. The frequency distribution of only RAD and ADV class fog onset for each month, coupled with sunset and dawn times (which are connected to the possibility for radiative cooling), is presented in Figure 14. Results indicate that in the fall, winter, and early spring, both RAD and ADV fog types are the most common forms (between October and March, the monthly sum of the frequency of these two categories is around 80%). For almost the whole year, radiation fog is more frequent than advection fog.

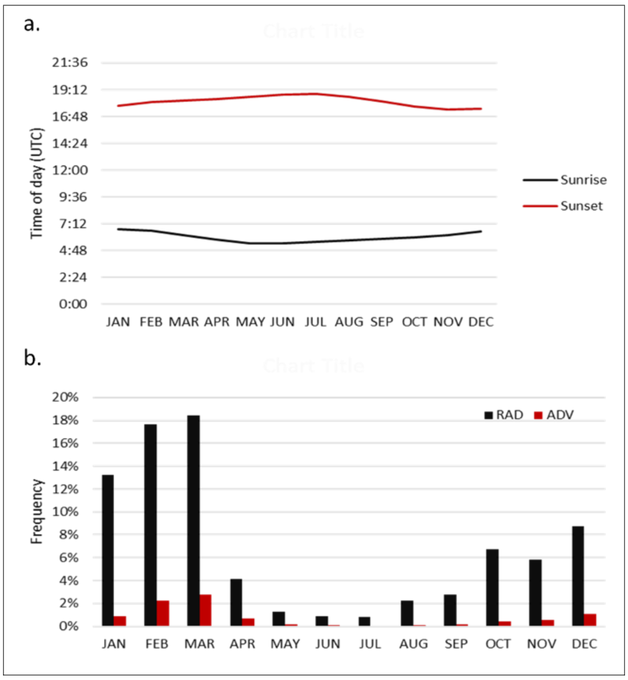

Figure 14: Composite time simulation of (a), sunrise (black) with sunset (red). And (b), monthly variation of the frequency occurrence of advection fog type (red bars) and frequency occurrence of radiation fog type (black bars), for VYYY during 2003-2021. The following was used to classify the types: (Tardif & Rasmussen, 2007).

The frequency of radiation fog type onset is highest in the earliest three months of each year. The climatological of study data show that the average monthly relative humidity during this time is over 80%, it is not surprising that there is a maximum surface cooling associated with the situation of clear skies above and light breezes. Additionally, throughout the months of October to March, monthly patterns in the advent of RAD fog type are favorable (***Figure 14***). The monthly frequency of ADV fog type onset increases from September through December and from January through March. February and March had the highest rates of RAD fog onset (17 and 18 percent, respectively) (18 percent) *Figure 14*. This is confirmed by the climatology parameter values for each month, which are consistent with the physical mechanisms of RAD fog described by Mason (1981).

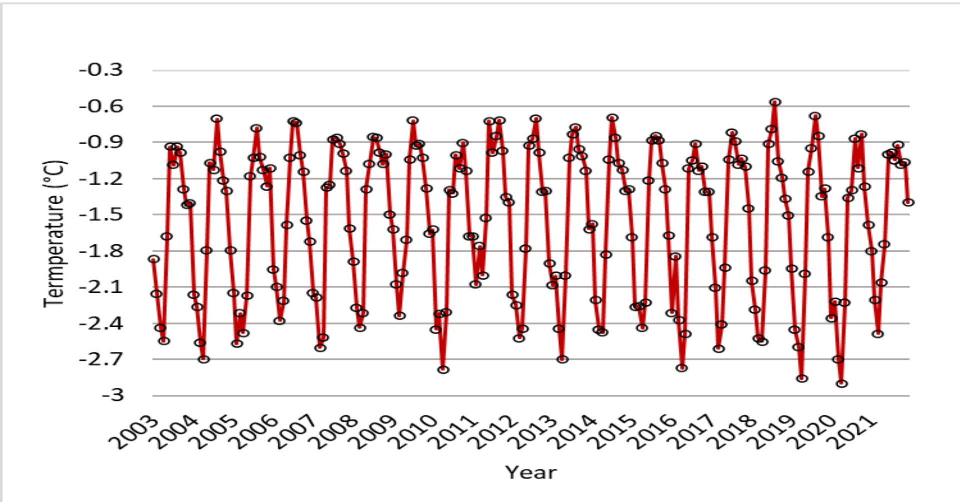

Figure 15: 00:00 UTC air–soil temperature differences, Tair–T7cm (in °C); during fog period at VYYY during the period 2003–2021

According to the classification made by (Petterssen, 1956), all fog event were liquid fogs are occurred in VYYY. Because of the aforementioned findings, fogs at VYYY always occurred at temperatures over 10 °C. According to ***Figure 15,*** the average temperature variation between air (T2m) and surface soil (T7cm) was about 1.6±0.3 °C.

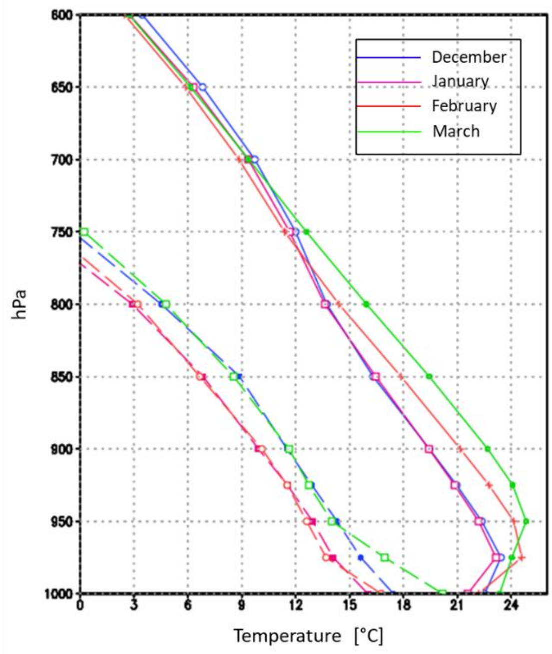

Figure 16: Vertical temperature profiles (solid colour lines) and dew-point temperature profiles (dashed lines of same colour) at 23:00-01:00 UTC during the winter (December-March) of 2003-2021.

Understanding the climatological characteristics of fog may be made easier by understanding how inversion layers affect microclimates. For the nineteen years, pressure level data at 00:00 UTC connected to the fog occurrence in the whole winter season and early spring season (from December to March) are given consideration to determine the temperature inversion with height and its strength. Data indicated that almost all time of fog events (90 percent) that forming at 00:00 UTC by surface-temperature inversions. The summaries include monthly temperature profiles. ***Figure 16*** displays the climatological monthly vertical temperature and dew-point vertical profile from the earth surface to 600 mb (about 14000 ft.) layers. When averaged over numerous fog events, January and February are the highest temperature inversion values and March is the largest inversion depths, which are roughly 300-600 meter thickness with 1-2.5 °C temperature changes from the inversion's base to its top. The biggest temperature inversions in the existence of fogs events are occurred during January and February (about 1 °C/300 m), whereas the shallowest inversion layer occurred in December (300 m deep) during the study period. The strength of the temperature inversions in DJF is similar to one another (1 °C/300 m). The warmest fogs events, 2° warmer than DJF, are found in March.

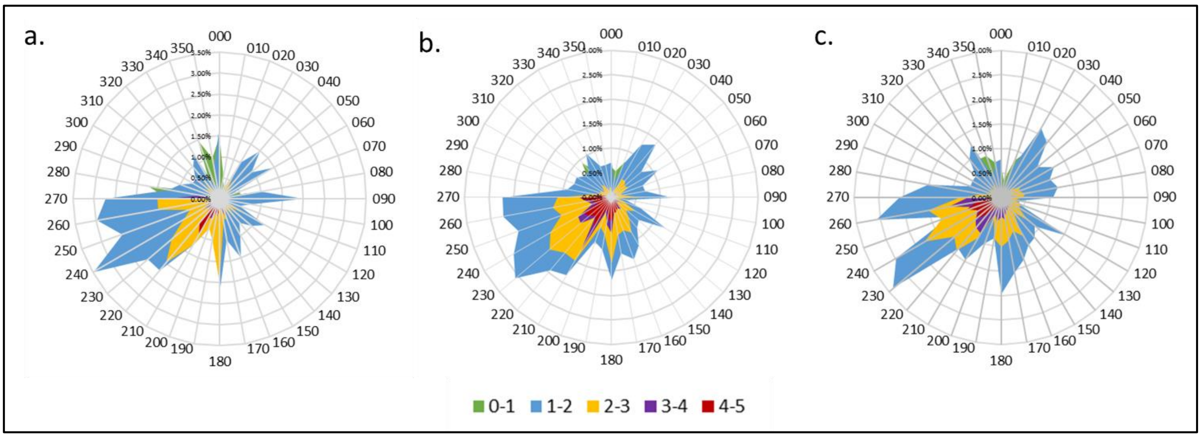

Figure 17: Wind rose (in m/s) for three phases of DJFM Fog events (a) Prior 1-hour onset, (b) During Fog, and (c) station observed dissipation phase data during 2003-2021

Fog is severely confined by local circulation, as indicated by the wind roses in Figure 17 that show composite of the climatology wind direction and velocity of events in December to March (DJFM). Figure 17a shows that an hour prior to the arrival of fog, the wind is most frequently from the west and east and is of low intensity wind (below 2 m/s). However, wind intensity is increasing with no change in direction during and dissipation phase of fog events (Figure 17b and c).

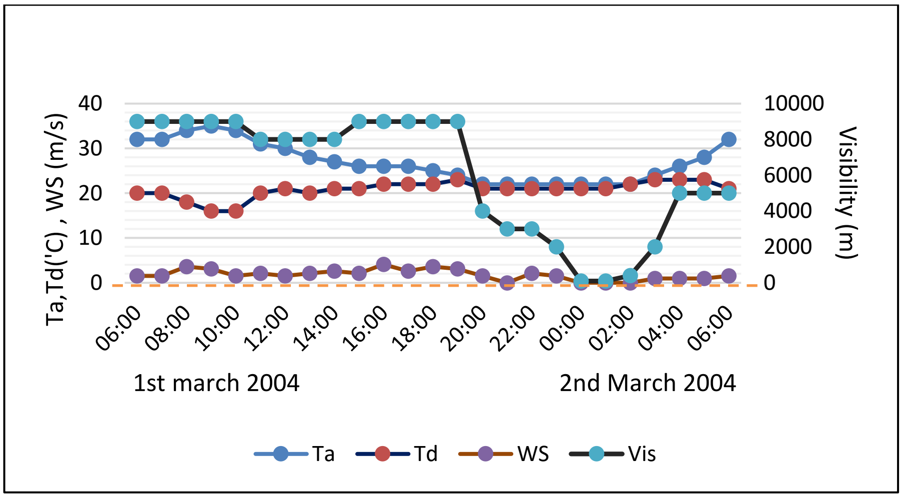

Figure 18: Wind intensity (WS) (m/s; left vertical axis), average temperature (Ta (in °C)), dew-point (Td (°C)), and visibility (Vis) (m; right vertical axis) with time (UTC) on first two days of March 2004. The dash green line denotes the 1,000-m line for visibility

According to Duynkerke (1991); Tardif and Rasmussen (2007); Haeffelin et al. (2013) definition, fog is more likely to form when the dew-point depression is in the stage of 2°C or lower and the maximum wind speed is 2.5 meter per second or less. After a few days of south-south-easterly winds, the fog formed. At initially, the winds were weak—below 2 meter per second—but by the time of this, mist and fog began to form. The mean temperature on March 2, 2004, when it was foggy, was matched the VYYY's typical fog event temperature of 21 °C (Figure 18). As this fog was clearly affected by solar heating and only persisted for a short time after sunrise, it can be categorized as a radiation type fog. (Figure 14 and Figure 18).

Each fog type's departure from sunrise and sunset, besides its horizontal visibility, duration, and intensity, can all be utilized to evaluate the way the fog behaves (minimum visibility). Overall, the results are as expected: fog requires moist air environment, weak winds, prolonged cooling during nighttime, and both synoptic and local scale, as seen in anticyclone weather.

The maximum frequency of annual prevailing wind comes from South and West during the whole year. In the winter months (NDJ), the prevailing wind come from the North. Wind calm condition is the maximum frequency in August. Fog and Haze weather phenomena are maximum occurred during winter. But Thunderstorms have occurred maximum during half of summer and the whole South-West monsoon season. For Yangon international airport, the visibility range had 600 to 9000 meters during the thunderstorm (TS) and thunderstorm rain (TSRA) conditions. The maximum visibility occurrences value is around 5000 meters and the minimum value is 600 meters. Average visibility will be 3500 m from 2009 to 2019 period. Maximum thunderstorm occurred in July and minimum frequency in January. No occurrences months are February, March, and December. In daily analysis, the maximum frequency of TSRA weather may occur 08:30 to 10:00 UTC during a day. The minimum frequency may occur from 19:00 to 2000 UTC.

Thunderstorm is the worst weather phenomena at VYYY and Fog condition is the worst also. Rain on airplane approach relative to poor visibility and the heavy gust wind also the worst weather phenomena at VYYY. But most are thunderstorm-related phenomena. Thus, we can assume that poor visibility, low ceiling, and Thunderstorm and Fog weather condition are the worst weather phenomena for Yangon international airport. We also got that visibility, cloud ceiling, and thunderstorm or Fog conditions are very important for airport and flight operation.

4. Conclusion

The climatology of VYYY, a key resource for the nation's economic gateway, may be learned from this study. It is possible for meteorology forecasters or professionals to gather a wealth of crucial and practical information, such as an analysis of the weather conditions that are most crucial or advantageous for aircraft operations. However in winter time the fog weather events are most prevalent. Furthermore, the southwest monsoon season of a year, and the first part of summer have historically seen the most thunderstorm activity. As result analysis the numerous weather events data of VYYY, we identified which events had a high impact on its daily operations. Notably, we discovered significantly that two weather conditions, TSRA and poor visibility, Mist or FG events, can influence aviation accident or operation delays, as seen in previous mentions. But among of these, TSRA provides a high risk than fog due to it associated with a number of related weather phenomena like wind shear, heavy precipitation and lightning. The paper also exhibited a new method to assess the tendency of fog events based on the use of the difficult fog criterion previously presented. Because the likelihood of fog occurrences under various atmospheric circumstances is measured at the VYYY.

According to study on annual frequency of occurrence, the average frequency of fog events is 527 during study period, with the lowest events occurred in 2010, 255 times, and the maximum events in 2018 with 920 times. As summary, TSRA days are exceeding year by year may be common as a result of climate change and further study are need to analysis. TSRA activity peaked the highest with 22 percentage of total events in July at VYYY.

Winter (DJFM) is the season when fog and other foggy weather conditions are most frequent. In comparison to summer and autumn, it was over six times higher and 1.5 times higher, respectively. Furthermore, criteria based on the primary physical factors responsible for fog production were used to divide fog events into two categories, advection and radiation conditions. When the wind speed was 2.5 meter per second or less and the dew-point depression was 2°C or lower, most fog events are occurred. Low visibility events are frequently occurred in the late evenings and early mornings, as the result of diurnal timescale and seasonal time scale analysis. This shows that radiation fog occurs frequently at VYYY and that it is mostly brought on by radiative cooling, especially in the morning hours of the fall. It is obvious that the number of fog events has also increased at the VYYY as TSRA in summer of a year. Could this potentially be a result of the urban area's increasing air pollution levels? Since the influence should be visible across a considerably greater area, a more thorough investigation than the one conducted in this paper would be needed to investigate this possibility.

Another implication of the current finding is for forecasters. As a result, in addition to studying other variables and simulating the model, we also need to achieve a realistic estimate of VYY. With the most recent finding, the prediction study will advance significantly and provide a fresh topic and alternative for interpreting climatology.

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